

eRD110: Photosensors for EIC Detectors

Photonis and Photek MCP PMTs

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Incom LAPPD/HRPPD

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SiPMs

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Photosensors for EIC Detectors

Already on the market

- Photonis (most mature, multi-anode MCP PMT), 10 μ m pore size, 5.3x5.3 cm²
- Photek (new, multi-anode MCP PMT), 6 μ m pore size, 5.3x5.3 cm²
- Incom LAPPD (new, capacitively-coupled multi-anode readout - needs validation for EIC), 20 μ m pore size, 20x20 cm²

In development by manufacturer

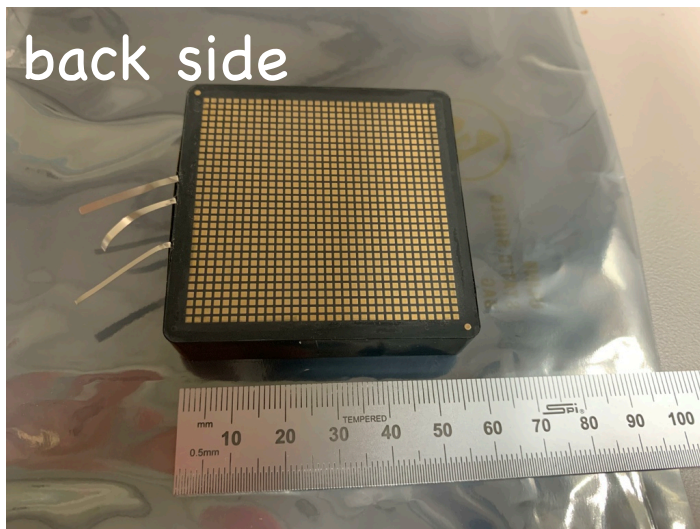
- Incom HRPPD (multi-anode direct readout), 10 μ m pore size, 10x10 cm²

On the market, but need some development for EIC

- SiPMs

Photonis MCP PMT

XP85122-S, HiCE



Specifications:

10 μm pore size

32x32 channels by design

16x16 configuration sufficient for EIC

B-field gain characterization:

completed in FY21 for two channels in 16x16 geometry

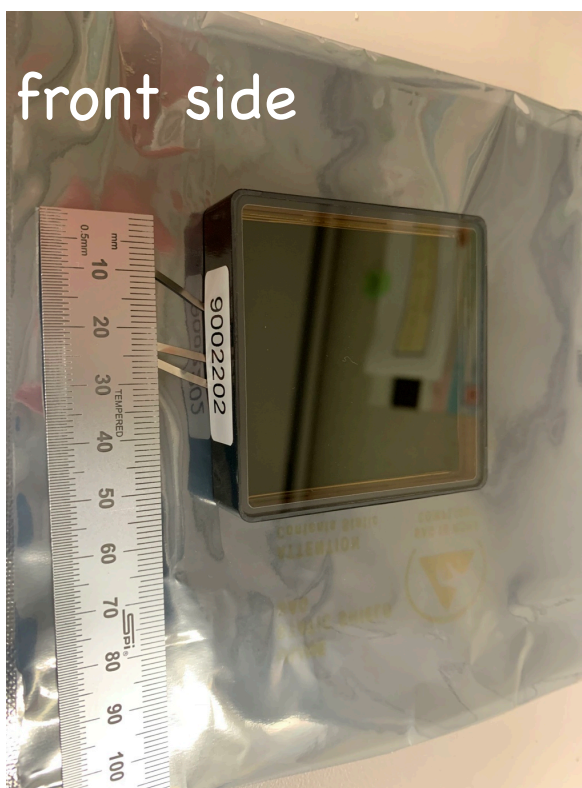
gain is within the specs up to 1.5 T

FY22 R&D:

tube response in full operation in **16x16 config**:
cross talk, collection efficiency (B-field), gain
uniformity, timing resolution

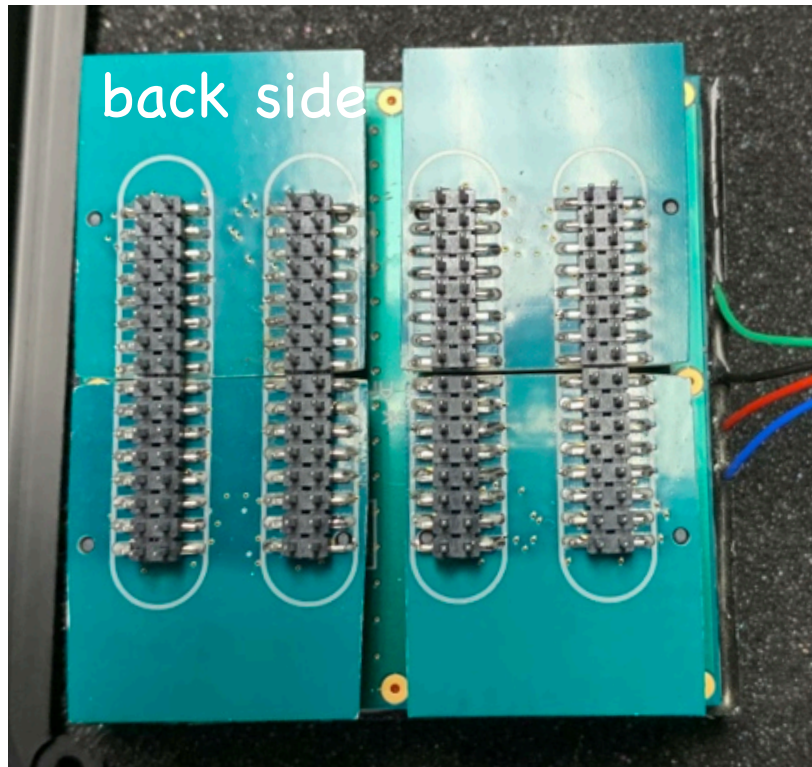
Good candidate for DIRC in all detectors

Good candidate for mRICH if $B \leq 1.5$ T



Photek MCP PMT

MAPMT253



Specifications:

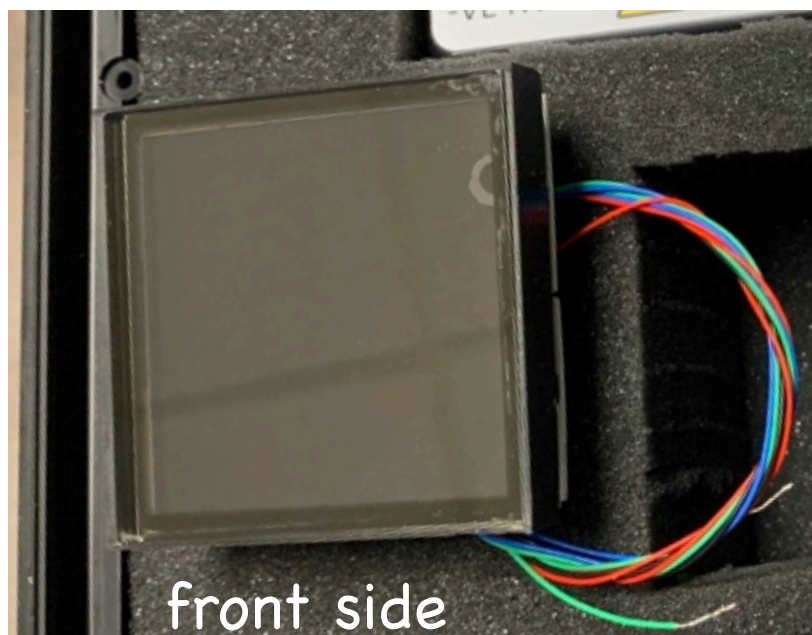
6 μm pore size (good for high B-fields)
16x16 channels by design – good for EIC

B-field gain characterization:

completed in FY21 for two channels in 8x8 geometry
gain is within the specs up to 2 T

FY22 R&D:

tube response in full operation in **16x16 config**:
cross talk, collection efficiency (B-field), gain
uniformity, timing resolution; needs **reliability**
track record



Good candidate for mRICH if $B \leq 2$ T

Good candidate for DIRC in all detectors

Photonis and Photek MCP PMTs

FY22 R&D effort

- Risk assessment of **collection efficiency**, timing resolution, **cross talk** and gain uniformity in B-fields over the full range of PMT response

Critically depends on complete readout solution in 16x16 configuration for each PMT (funding of HU efforts on PMT readout is crucial – part of DIRC proposal)

FY22 Budget (no overhead included) \$54k total

Covers 4 weeks of B-field data taking and 4 weeks of setup and bench tests

JLab

- Cryogenics \$11k
- Small components \$3k

USC

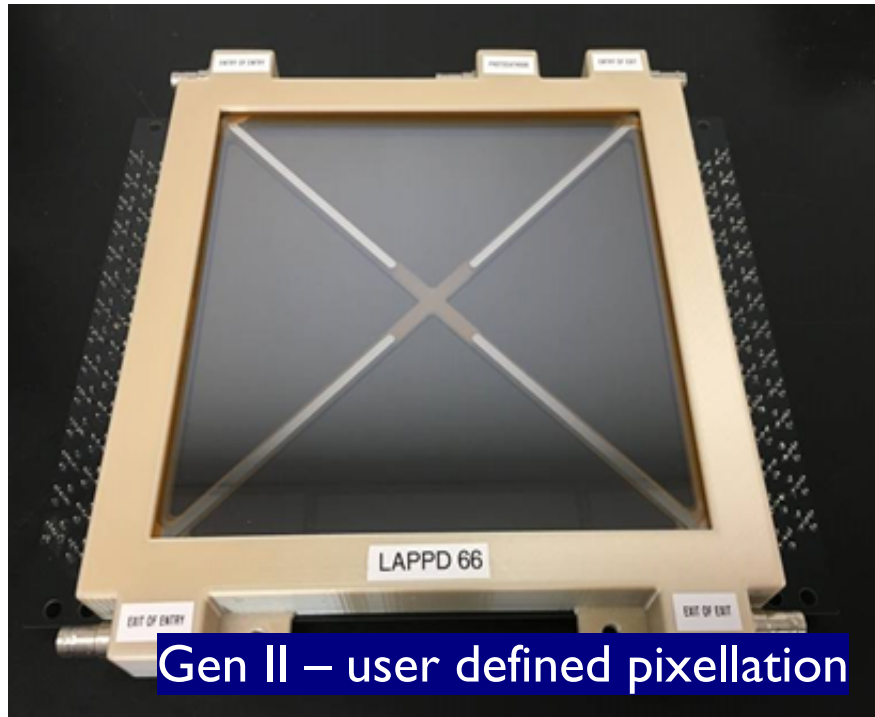
- Salary of 1 undergraduate student \$5k
- 2-month travel to JLab for one faculty and two students: \$14k
- cost of one unit Photek MAPMT253 \$16k
- rental scope \$5k

FY23, FY24 R&D effort

- Any risk mitigation characterization that still needs to be performed

Incom LAPPDs / HRPPDs

20cm LAPPD



Varieties:

10 μm and 20 μm pore size
10x10 cm^2 and 20x20 cm^2 formfactor

Charge collection schemes:

- Gen I (DC coupled strips)

- Gen II (Capacitive coupling)

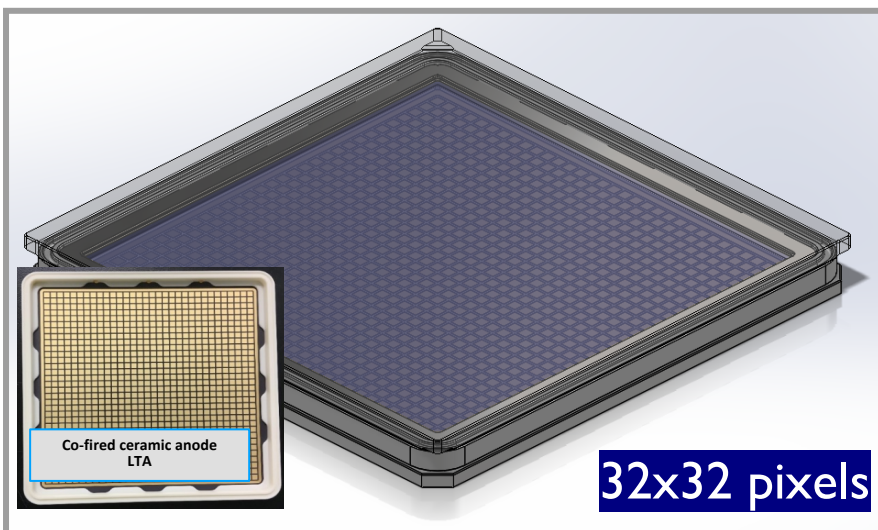
- "HRPPD" (DC coupled pixels; through vias)

sensor area
 $\sim 3 \text{ m}^2$ $\sim 3 \text{ m}^2$

mRICH, dRICH
DIRC

$\sim 1.5 \text{ m}^2$

10cm HRPPD



FY22 R&D:

Full bench and beam test characterization of **four distinct types of devices**: QE and gain uniformity, cross-talk, spatial and timing resolution, magnetic field and rate tolerance

Deliverables:

Performance reports and a preliminary assessment for application at the EIC

Cost (compared to other MCP-PMTs) and technical risk
(if SiPMs can not be used) mitigation

LAPPDs: samples to study in FY22; costs

| | | | | | | | | | | | | | |
|--|--|--|--|--|--|--|------|------|------|-----------------------|------|-----------------------|-----|
| PENDING ORDERS VARIOUS GEN II, HRPPD FOUR TILES Alexander Kiselev BNL - EIC Timing & Specs TBD | 20 cm GEN II LAPPD 20micron pores, | | | | | | XXXX | XXXX | XXXX | XXXX | | | |
| | 20 cm GEN II LAPPD 10micron pores, | | | | | | | XXXX | XXXX | XXXX | XXXX | | |
| | HRPPD (10cm) 10-micron gapped MCPs Capacitively Coupled Readout (GEN II Style), | | | | | | | | XXXX | Incom - Ready for EIC | XXXX | XXXX | |
| | HRPPD (10cm) 10-micron gapped MCPs co-fired ceramic base 1024 Direct Readout Anodes | | | | | | | | | XXXX | XXXX | Incom - Ready for EIC | xxx |

Jan'2022

beam test

Jul'2022

| # Sold | LAPPD Unit Price (380 cm ² area) | Cost / cm ² |
|--------|--|------------------------|
| 1 | \$ 50,000 | \$ 131.58 |
| 2 | \$ 47,044 | \$ 123.80 |
| 3 | \$ 43,440 | \$ 114.31 |
| 4 | \$ 41,461 | \$ 109.11 |
| 5 | \$ 40,111 | \$ 105.56 |
| 6 | \$ 39,095 | \$ 102.88 |
| 7 | \$ 38,284 | \$ 100.75 |
| 8 | \$ 37,611 | \$ 98.98 |
| 9 | \$ 37,038 | \$ 97.47 |
| 10 | \$ 36,540 | \$ 96.16 |
| 20 | \$ 36,100 | \$ 95.00 |
| 50 | \$ 33,334 | \$ 87.72 |
| 75 | \$ 30,000 | \$ 78.95 |
| 100 | \$ 28,633 | \$ 75.35 |
| 300 | \$ 27,702 | \$ 72.90 |
| 500 | \$ 24,414 | \$ 64.25 |
| 750 | \$ 23,021 | \$ 60.58 |
| 1000 | \$ 21,972 | \$ 57.82 |

- 1) 20cm, 20 μ m pores Gen II - a familiar baseline model
- 2) 20cm, 10 μ m pores Gen II
- 3) 10cm, 10 μ m pores, short stack capacitively coupled HRPPD
- 4) 10cm, 10 μ m pores, short stack DC-coupled HRPPD with internal pixels

- Full Manufacturing High Volume Price Target = \$10,000 / LAPPD (\$26/cm²)
- Compare: Photonis Planacon @ \$428/cm²

← Incom cost projection per volume

LAPPDs: groups, equipment, budget request

Argonne: QE, gain, B-field measurements

BNL: pixelization

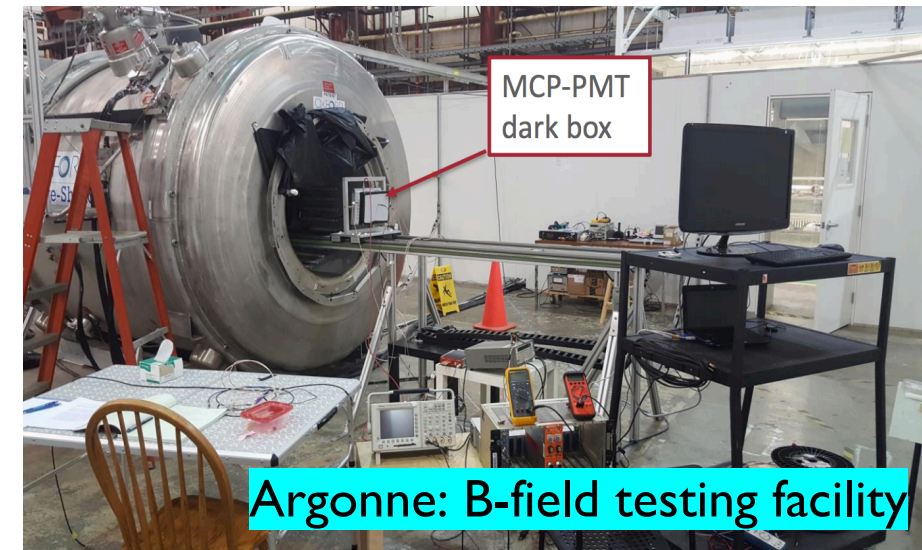
INFN: timing resolution, data analysis

MSU: data analysis

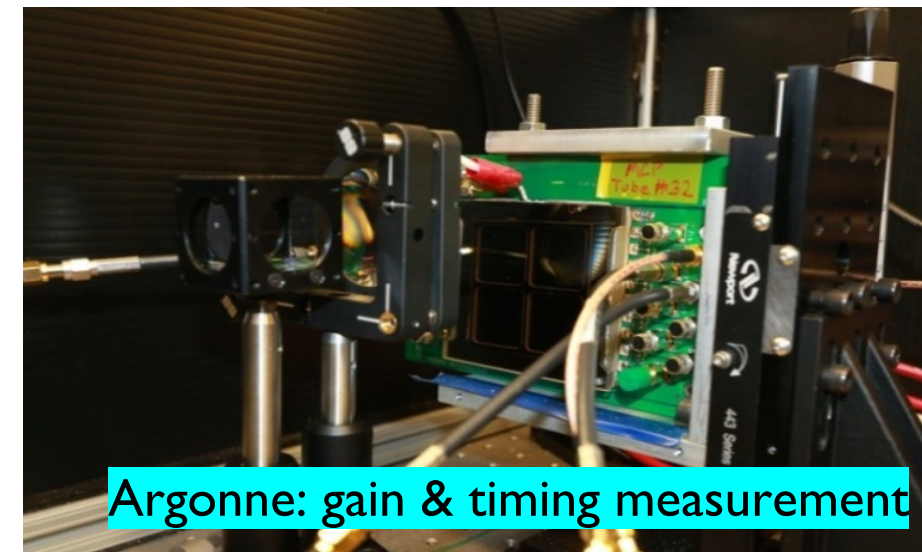
Argonne facilities require upgrade to a 20cm size
INFN is setting up a test stand starting Nov'2021

\$12k per a four-months rental

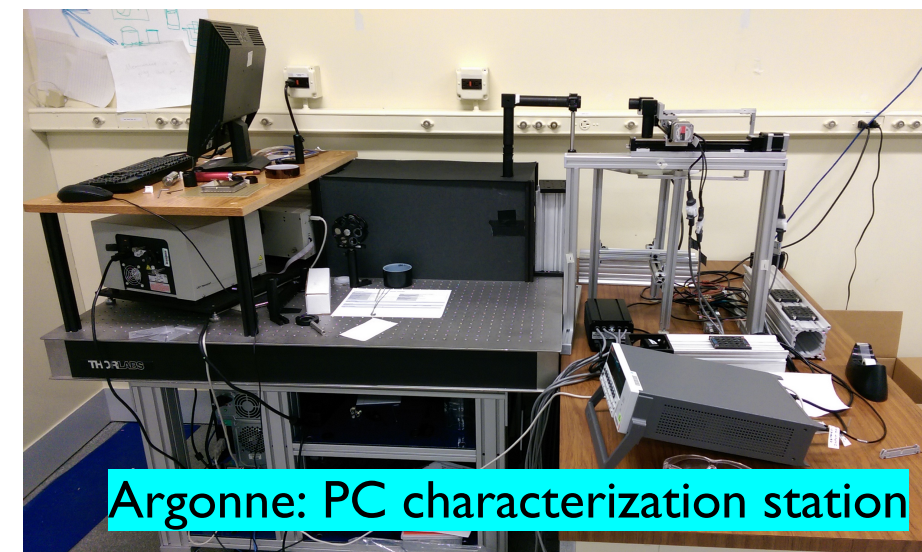
| | ANL | BNL | INFN | MSU |
|--|-----------------|-----------------|-----------------|----------------|
| LAPPD rental | | \$48,000 | | |
| SiPMs and related equipment | | | \$30,000 | |
| ANL B-field facility upgrade, Helium consumption | \$18,000 | | | |
| Gen II readout boards | | \$10,000 | | |
| HRPPD readout interface | | \$7,000 | | |
| Staff effort support | \$50,000 | | | |
| Engineering/technical support | \$12,000 | \$7,000 | | |
| LAPPD test stand equipment | | \$5,000 | \$15,000 | |
| Postdocs and students | | | \$50,000 | \$2,500 |
| Travel | \$3,000 | \$7,000 | | \$5,000 |
| Photek 16x16 MAPMT253 | | | | |
| Cryogens for High-B at JLab | | | | |
| Small components for High-B at JLab | | | | |
| Fast Oscilloscope Rental (JLab) | | | | |
| TOTAL | \$83,000 | \$84,000 | \$95,000 | \$7,500 |



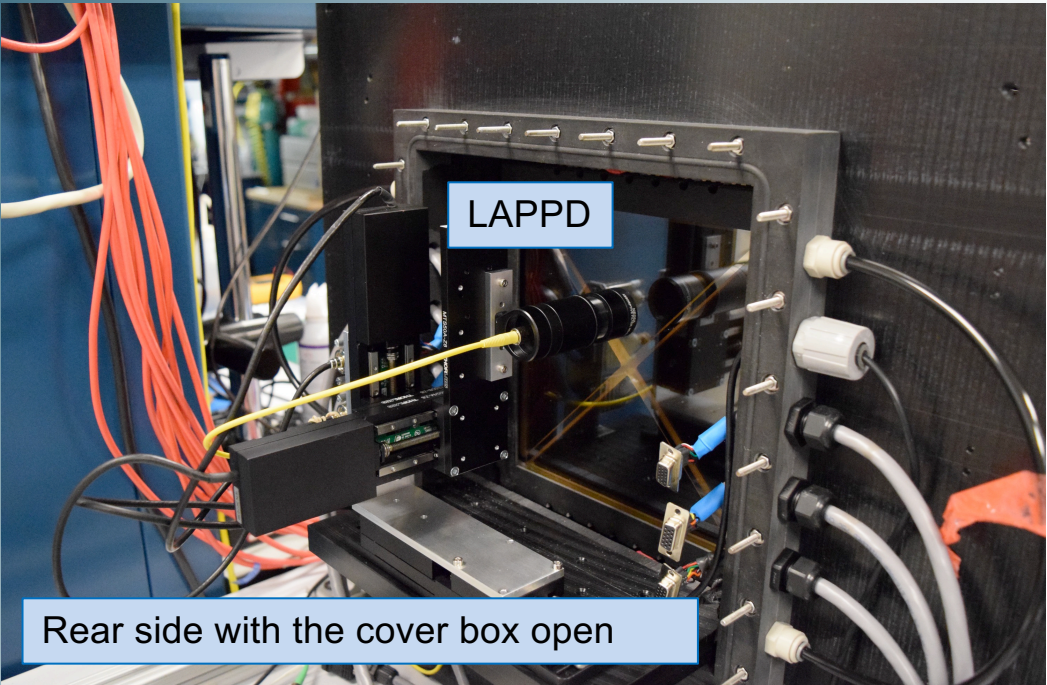
Argonne: B-field testing facility



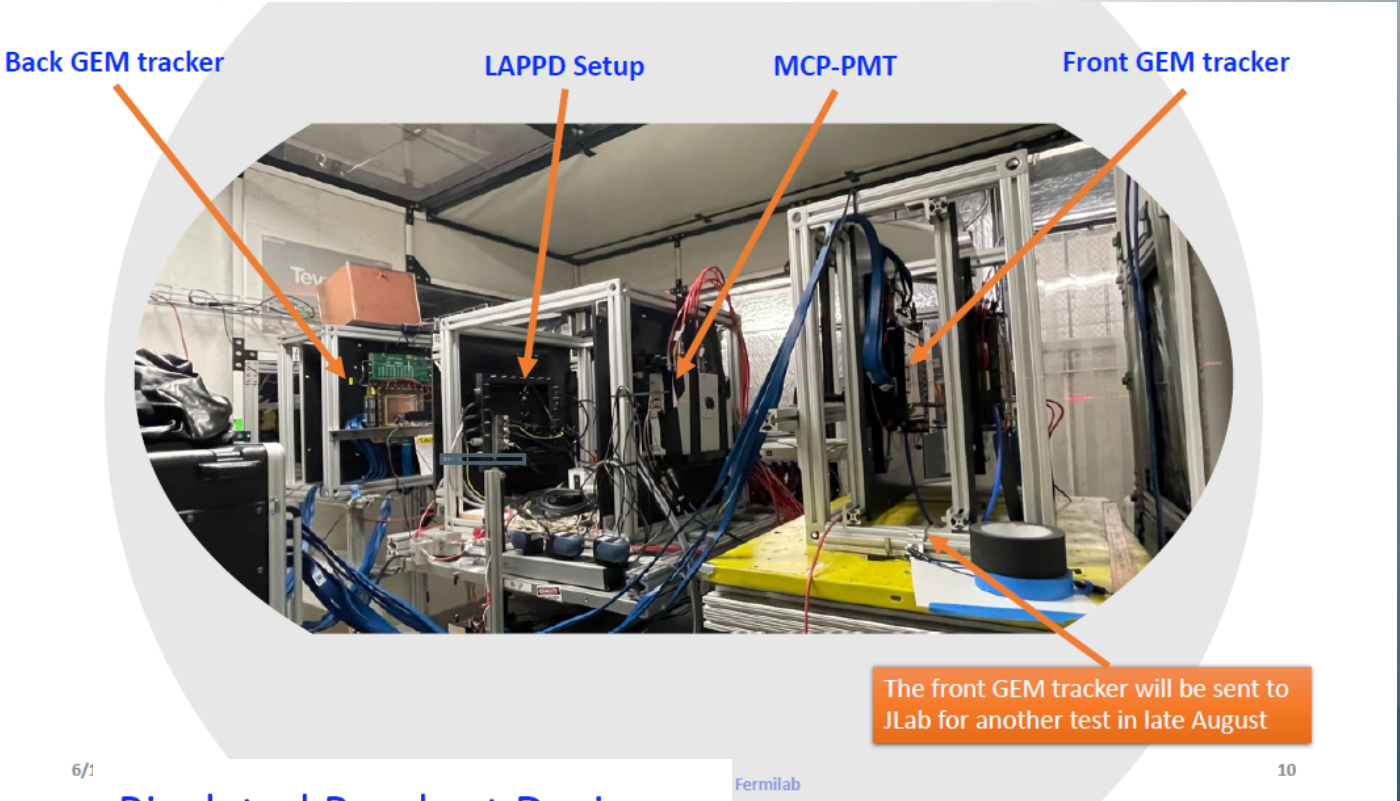
Argonne: gain & timing measurement



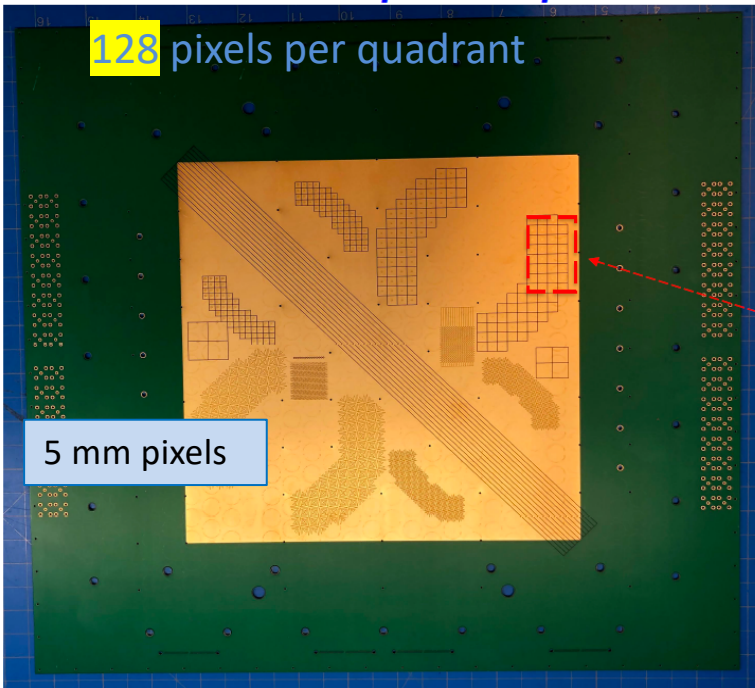
Argonne: PC characterization station



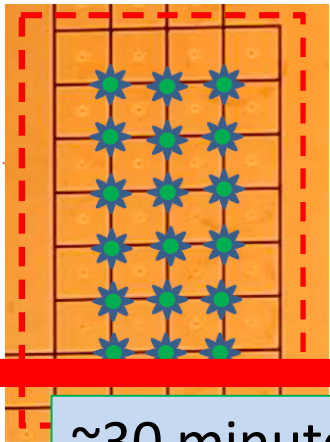
Rear side with the cover box open



Tile #66 & square pads on L00i board

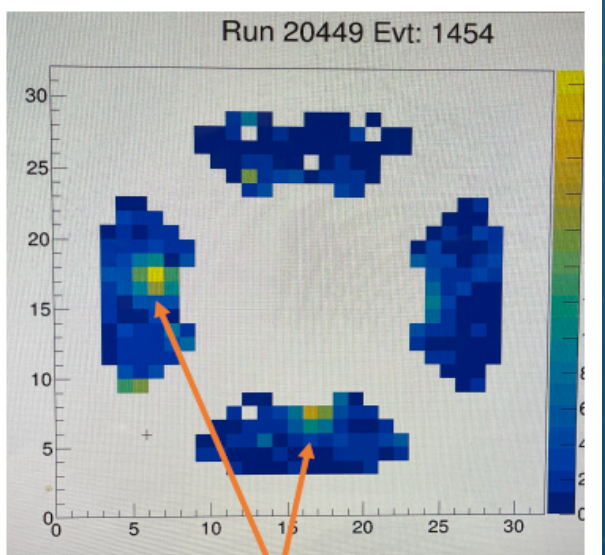
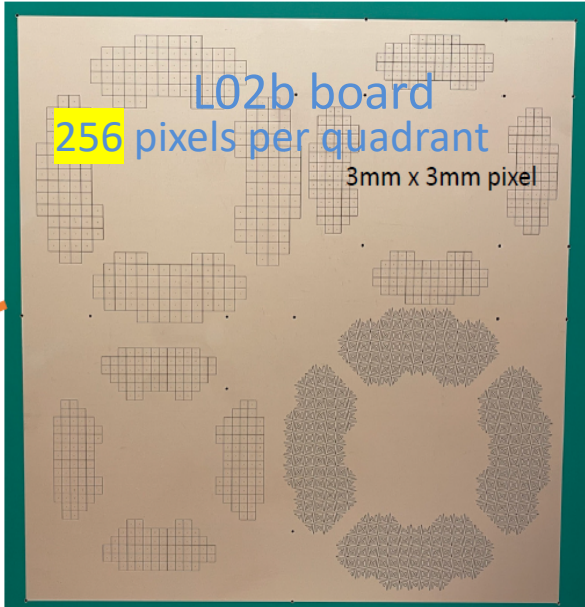


- Use a similar 4x7 pixel field, but with square pads
- Illuminate 2x2 areas



~30 minutes swap in / out

Pixelated Readout Design



Likely a single-photon hit

- Several photon sources have been used during the test: laser, photons from LAPPD glass window, Aerogel (mRICH like), aspherical lens, for characterizing the LAPPD properly
- Future test of LAPPD will be needed to verify its performance for EIC RICH-based PID detectors